METHODS AND APPARATUS FOR FACILITATING MANUFACTURING

BACKGROUND OF THE INVENTION

[0001] This invention relates generally to computer modeling and designing, and, more particularly, to manufacturing an object using a computer model.

[0002] In manufacturing, an initial design phase includes designing a part, then choosing materials for the part and determining a process to make the part. Typically, as part of the design phase, the manufacturer will generate a computer model of the part utilizing computer modeling tools, such as, for example, Pro/ENGINEER commercially available from Parametric Technology Corporation, Waltham, Mass. The manufacturer will then extract a plurality of design parameters from the modeling tool, and manually enter the design parameters into a planning tool, such as, for example, Macola commercially available from Exact Software, Andover, Mass. The tooling used to fabricate the part is then selected based on the planning program.

[0003] Manually inputting design information into a planning tool facilitates an increase in a quantity of time to manufacture a part. Further, for complex parts, an increased amount of time may be used by the manufacturer to input the design into the planning program which may facilitate an increase in cost of the finished part.

BRIEF DESCRIPTION OF THE INVENTION

[0004] In one aspect, a method for facilitating manufacturing is provided. The method includes generating a computer model of an object using a design program, automatically extracting at least a portion of the computer model from the design program and automatically inputting the extracted portion into a planning program, and fabricating the object using the planning program.

[0005] In another aspect, an apparatus for facilitating manufacturing is provided. The apparatus includes at least one manufacturing tool, and a computer coupled to the manufacturing tool and configured to generate a computer model of an object using a design program, automatically input at least a portion of the computer model into a planning program, and fabricate the object using the manufacturing tool based on the planning program.

[0006] In a further aspect, a computer for facilitating manufacturing is provided. The computer is configured to at least one of generate and receive a computer model of an object generated using a design program, and automatically input at least a portion of the computer model into a planning program.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] Figure 1 illustrates a method for facilitating manufacturing.

[0008] Figure 2 is a process map of one embodiment of automatically inputting at least a portion of a computer model into a planning program.

[0009] Figure 3 is a perspective view of a part manufactured according to the processes described herein.

[0010] Figure 4 is a perspective view of the part illustrated in Figure 3 with a single feature modified.

[0011] Figure 5 is a perspective view of a subassembly manufactured according to the processes described herein.

[0012] Figure 6 is a perspective view of the subassembly illustrated in Figure 3 with a single feature modified.

[0013] Figure 7 is process map for one embodiment of a method for generating computer models.

DETAILED DESCRIPTION OF THE INVENTION

[0014] Figure 1 is a method 10 for facilitating manufacturing, wherein method 10 includes generating 12 a computer model of an object using a design program installed on a computer, automatically 14 inputting at least a portion of the computer model into a planning program, and fabricating 16 the object using the planning program.

[0015] In an exemplary embodiment, the computer model is a solid model of a top-level assembly, i.e. a completed assembly, and is generated utilizing a computer modeling tool. In one embodiment, the top-level assembly includes at least one sub-assembly. In another embodiment, the top-level assembly is unitary and does not include any sub-assemblies. In another embodiment, the top-level assembly includes a plurality of parts capable of being assembled into a single top-level assembly. The solid model is a computer description of a closed, solid, three-dimensional shape which can be completely defined. Generating a solid model of a top-level assembly facilitates ensuring that all the spatial information is available for any subsequent analysis directly from the solid model itself. Further, a plurality of structural and material properties can be computed at any arbitrary point in the solid model or along any points of an arbitrarily directed ray at any time. Further, generating a solid model facilitates generating drawings or pictures of the modeled object, i.e. the top-level assembly, from any viewpoint.

[0016] Figure 2 is a process map of one embodiment of automatically 14 inputting at least a portion of the computer model into an automatic planning program. An automatic planning program, as used herein, refers to a program configured to automatically capture the solid model information from a program used to generate the solid model, and automatically output a plurality of operational steps to fabricate the top-level assembly.

[0017] In use, all operations to fabricate the top-level assembly are captured from the program used to generate the solid model information. In the exemplary embodiment, the automatic planning program captures or extracts a plurality of solid model information from the computer modeling program and uses the extracted data to generate a planning program to fabricate a physical structure, i.e. the top-level assembly. The operations generated by the planning program include all operations or steps to fabricate the top-level assembly including any subassemblies or parts included in the top-level assembly. In an exemplary embodiment, the automatic planning program generates a list of steps in sequential order, i.e. the order in which the top-level assembly, the subassemblies, or at least one part, is fabricated from a first step to a last step.

[0018] Once the list of steps is generated for the top-level assembly, the planning program is activated such that the selected sub-assemblies or parts are fabricated. If a portion of the top-level assembly is not selected, the portion of the planning program associated with fabricating this subassembly or part is not turned on. In other words, the operator may desire to fabricate a top-level assembly that does not include a specific subassembly or part. The planning program is configured to recognize any subassembly or part that has not been selected, or any subassembly or part that has been modified, by the operator and automatically skip the steps to fabricate this subassembly or part during the fabrication process.

[0019] Figure 3 is a perspective view of a part 20 manufactured according to the processes described herein. Figure 4 is a perspective view of part 20 illustrated in Figure 3 with a single feature 22 modified. In an exemplary embodiment, the planning program for part 20 shown in Figure 3 includes:

OPERATION 010 FLAME CUT EXTERIOR TO DRAWING
OPERATION 020 FLAME CUT INTERIOR HOLE TO DRAWING
OPERATION 030 PREP FOR WELDING

[0020] If feature 22 (i.e. hole 22) is not desired, as shown in Figure 4, the planning program is automatically modified, and the modified fabrication plan includes:

OPERATION 010 FLAME CUT EXTERIOR TO DRAWING
OPERATION 020 NOT REQUIRED
OPERATION 030 PREP FOR WELDING

[0021] As shown above, operation 020 has not been performed because hole 22 was not desired by the operator, therefore the planning program is automatically updated to skip this step.

[0022] Figure 5 is a perspective view of a subassembly 30 manufactured according to the processes described herein. Figure 6 is a perspective view of subassembly 30 illustrated in Figure 5 with a feature 32 modified. In an exemplary embodiment, fabrication planning for subassembly 30 shown in Figure 5 includes:

TOP ASSEMBLY OPERATION 010 SET UP ON MILLING MACHINE
TOP ASSEMBLY OPERATION 020 BORE OUT AS PER DRAWING
TOP ASSEMBLY OPERATION 030 DRILL ALL HOLES AS REQUIRED
SUB ASSEMBLY OPERATION 010 CLEAN ALL PARTS
SUB ASSEMBLY OPERATION 020 WELD ALL SIDES AS PER DRAWING
SUB ASSEMBLY OPERATION 030 WELD BOTTOM PLATE AS PER DRAWING
PART ONE OPERATION 010 FLAME CUT TO DRAWING
PART ONE OPERATION 020 PREP FOR WELDING
PART FOUR OPERATION 010 FLAME CUT TO DRAWING
PART FOUR OPERATION 020 PREP FOR WELDING
PART TWO OPERATION 010 FLAME CUT TO DRAWING
PART TWO OPERATION 020 PREP FOR WELDING
PART THREE OPERATION 010 FLAME CUT EXTERIOR TO DRAWING
PART THREE OPERATION 020 FLAME CUT INTERIOR HOLE TO DRAWING
PART THREE OPERATION 030 PREP FOR WELDING

[0023] If feature 32 (i.e. hole 32) is not desired and a back plate 34 is not desired, as shown in Figure 6, the planning program is automatically modified, and the modified planning program includes:

TOP ASSEMBLY OPERATION 010 SET UP ON MILLING MACHINE
TOP ASSEMBLY OPERATION 020 BORE OUT AS PER DRAWING
TOP ASSEMBLY OPERATION 030 DRILL ALL HOLES AS REQUIRED
SUB ASSEMBLY OPERATION 010 CLEAN ALL PARTS
SUB ASSEMBLY OPERATION 020 WELD ALL SIDES AS PER DRAWING
SUB ASSEMBLY OPERATION 030 WELD BOTTOM PLATE AS PER DRAWING
PART ONE OPERATION 010 FLAME CUT TO DRAWING
PART ONE OPERATION 020 PREP FOR WELDING
PART TWO OPERATION 010 FLAME CUT TO DRAWING
PART TWO OPERATION 020 PREP FOR WELDING
PART THREE OPERATION 010 FLAME CUT EXTERIOR TO DRAWING
PART THREE OPERATION 020 NOT REQUIRED
PART THREE OPERATION 030 PREP FOR WELDING

[0024] As shown above, hole 32 and back plate 34 were not desired by the operator, therefore the planning program is automatically modified to skip these steps.

[0025] Once the planning program is generated for the desired top-level assembly, the tooling information is generated to manufacture features that are included in the top-level assembly. In an exemplary embodiment, the presence or absence of the desired features will turn on or off the tooling used to fabricate these features. In another exemplary embodiment, the presence and/or absence of a certain assembly component may also turn on or off certain tooling. For example, the planning program generates a list of all the tooling used to fabricate the top-level assembly including all subassemblies and parts. If another data file is executed which changes the planning program, for example by adding or deleting subassemblies or parts from the top-level assembly, the tooling information for the top-level assembly will automatically update to reflect the desired changes.

[0026] Figure 7 is a process map for one embodiment of automatically 14 inputting at least a portion of the computer model into a tooling program. Tooling program as used herein, refers to a program configured to capture the solid model information from the program used to generate the solid model, and output a list of tools used to fabricate the top-level assembly. In an exemplary embodiment, a computer including the planning program is coupled to at least one tool and is configured to receive information from the planning program and automatically select the tool based on the planning program. The planning program then directs the tool to perform a desired operation, e.g., cut, drill, punch, press, roll, bend, knurl, heat treat, anneal, anodize, polish, machine, etc.

[0027] In use, a tooling list to fabricate the top-level assembly is captured from the program used to generate the solid model information. The tooling list includes all tools used to fabricate the top-level assembly including any subassemblies or parts included in the top-level assembly. In one embodiment, the tooling list is extracted from the program used to generate the top-level assembly using the planning program. In another embodiment, the tooling list is not extracted using the planning program. In an exemplary embodiment, the tooling list is generated in sequential order, i.e. the order in which the top-level assembly, the subassemblies, or at least one part, is fabricated from a first tool used to a last tool used.

[0028] Once the tooling list is generated for the top-level assembly, the planning program is activated such that the selected sub-assemblies or parts are fabricated. If a portion of the top-level assembly is not selected, the portion of the tooling list associated with fabricating this subassembly or part is not turned on. In other words, the operator may desire to fabricate a top-level assembly that does not include a specific subassembly or part. The planning program is configured to recognize any subassembly or part that has not been selected, or any subassembly or

part that has been modified, by the operator and automatically delete the tool used to fabricate this subassembly or part during the fabrication process.

[0029] In an exemplary embodiment, fabrication tooling for part 20 shown in Figure 3 includes:

OPERATION 010 FLAME CUT EXTERIOR TO DRAWING
OPERATION 020 FLAME CUT INTERIOR HOLE TO DRAWING
OPERATION 020 TOOL NUMBER MS XXX 2.00 JNCI-I MILL
OPERATION 030 PREP FOR WELDING

[0030] If hole 22 (shown in Figure 3) is not desired, as shown in Figure 4, the fabrication tooling is automatically modified, and the modified fabrication plan includes:

OPERATION 010 FLAME CUT EXTERIOR TO DRAWING
OPERATION 020 NOT REQUIRED
OPERATION 030 PREP FOR WELDING

[0031] As shown above, operation 020 has not been performed because the hole was not desired by the operator, thereby automatically updating the program to skip this step and also delete the tool used to perform operation 020.

[0032] In an exemplary embodiment, fabrication tooling for subassembly 30 (shown in Figure 5) includes:

TOP ASSEMBLY OPERATION 010 SET UP ON MILLING MACHINE
TOP ASSEMBLY OPERATION 020 BORE OUT AS PER DRAWING
TOP ASSEMBLY OPERATION 030 DRILL ALL HOLES AS REQUIRED
SUB ASSEMBLY OPERATION 010 CLEAN ALL PARTS
SUB ASSEMBLY OPERATION 020 WELD ALL SIDES AS PER DRAWING
SUB ASSEMBLY OPERATION 030 WELD BOTTOM PLATE AS PER DRAWING
PART ONE OPERATION 010 FLAME CUT TO DRAWING
PART ONE OPERATION 020 PREP FOR WELDING
PART FOUR OPERATION 010 FLAME CUT TO DRAWING

PART FOUR OPERATION 020 PREP FOR WELDING
PART TWO OPERATION 010 FLAME CUT TO DRAWING
PART TWO OPERATION 020 PREP FOR WELDING
PART THREE OPERATION 010 FLAME CUT EXTERIOR TO DRAWING
PART THREE OPERATION 020 FLAME CUT INTERIOR HOLE TO DRAWING
PART THREE OPERATION 020 TOOL NUMBER MS XXX 2.00 INCH MIL.L
PART THREE OPERATION 030 PREP FOR WELDING

[0033] If hole 32 and plate 34 are not desired, as shown in Figure 6, the fabrication planning is automatically modified, and the modified fabrication plan includes:

TOP ASSEMBLY OPERATION 010 SET UP ON MILLING MACHINE
TOP ASSEMBLY OPERATION 020 BORE OUT AS PER DRAWING
TOP ASSEMBLY OPERATION 030 DRILL ALL I-IOLES AS REQUIRED
SUB ASSEMBLY OPERATION 010 CLEAN ALL PARTS
SUB ASSEMBLY OPERATION 020 WELD ALL SIDES AS PER DRAWING
SUB ASSEMBLY OPERATION 030 WELD BOTTOM PLATE AS PER DRAWING
PART ONE OPERATION 010 FLAME CUT TO DRAWING
PART ONE OPERATION 020 PREP FOR WELDING
PART TWO OPERATION 010 FLAME CUT TO DRAWING
PART TWO OPERATION 020 PREP FOR WELDING
PART THREE OPERATION 010 FLAME CUT EXTERIOR TO DRAWING
PART THREE OPERATION 020 NOT REQUIRED
PART THREE OPERATION 030 PREP FOR WELDING

[0034] As shown above, the tooling program has been modified by the operator to delete hole 32 and plate 34, thereby automatically updating the planning program to skip this step and remove the tool used to perform this step from the tooling list.

[0035] Automatically extracting model data from the modeling program facilitates reducing the time expended by the manufacturer to manufacture a part by eliminating the need to manually input design information into a planning tool. Accordingly, once the part is designed, the design information and tooling list can be

extracted automatically facilitating a decrease in time to produce the part, and facilitating a decrease in time to make any desired modifications to the part, resulting in a decrease in cost to the manufacturer.

[0036] While the invention has been described in terms of various specific embodiments, those skilled in the art will recognize that the invention can be practiced with modification within the spirit and scope of the claims.